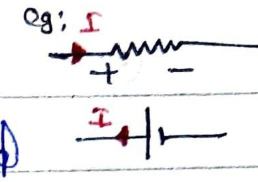
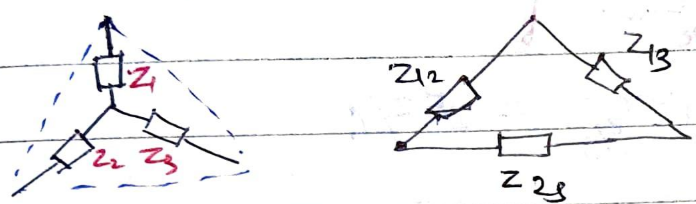
Basic concepts of Network

- If current enters +ve terminal P = absorbed
- If current leaves +ve terminal P = delivered

eg:



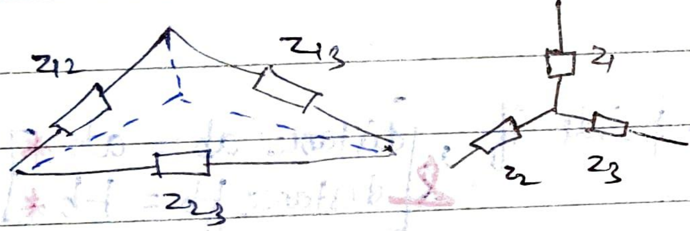
(i) Y to Δ conversion



$$\boxed{Z_{12} = \frac{Z_1Z_2 + Z_2Z_3 + Z_1Z_3}{Z_3}} \quad \text{— (i)}$$

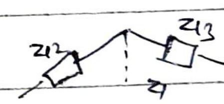
Samne wali Khidki me

(ii) Δ to Y conversion



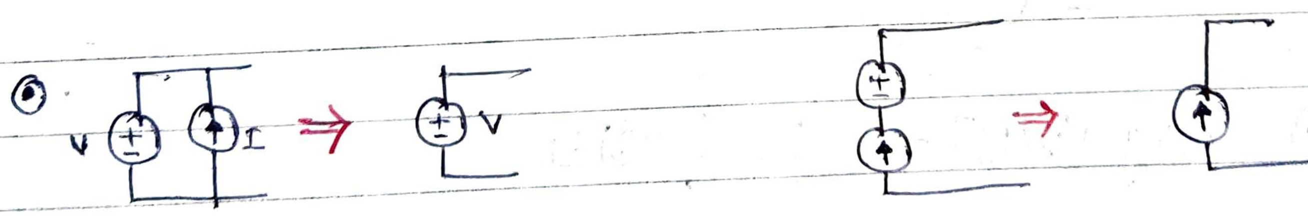
$$\boxed{Z_1 = \frac{Z_{12}\, Z_{13}}{Z_{12} + Z_{23} + Z_{13}}} \quad \text{— (ii)}$$

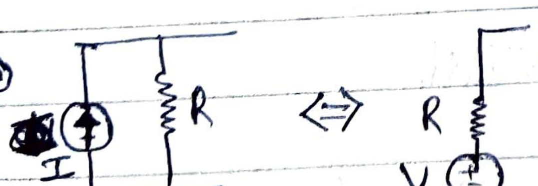
Adosi Padosi



* Note in both (i) & (ii) N^r contains $\Omega \times \Omega$ {Z^2 terms}

$$\text{STAR} \xrightarrow[C \times 1/3]{R \times 3} \text{DELTA} \xrightarrow[C \times 3]{R/3} \text{STAR}$$

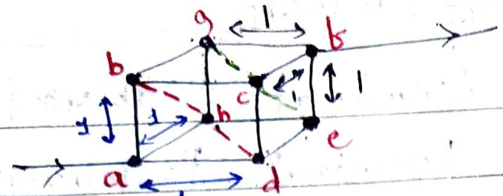




where $V = IR$

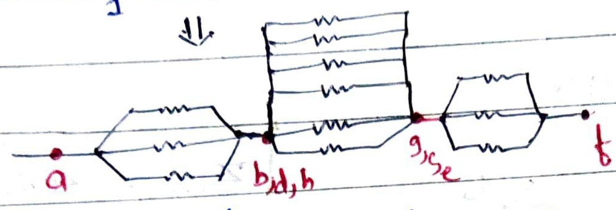
$I = V/R$

* Source transformation is not valid for controlling variable branch but it is valid for dependent source

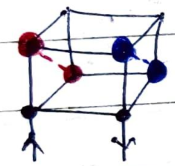
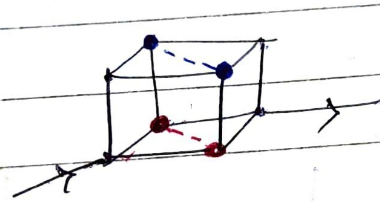
⊙ 

equipotential pnds

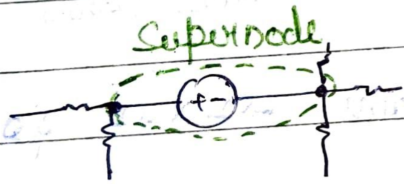
⇓



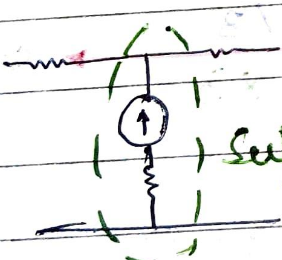
$\underbrace{}_{\frac{Z}{3}} + \underbrace{}_{Z/6} + \underbrace{}_{Z/3} = 5Z/6$

⊙  

Note! b & h are equipot. points if, [distance ab = ah * & distance fb = fh *]

⊙ 

Supernode = KCL + KVL + Ohm's law

⊙ 

Supermesh = KVL + ohm's law + KCL

⊙ $\text{Avg}[x(t)] = \frac{1}{T}\int_0^T x(t)\,dt$

$\text{RMS}[x(t)] = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt}$

$\text{RMS} = \sqrt{DC^2 + \left(\frac{AC}{\sqrt{2}}\right)^2}$ for $x(t) = D_C + A_C \sin\omega t$

Two port N/W

* for 'n' variable, 'r' port N/W, No. of possible parameters are ^nC_r

  eg: 4 variable 2 port ⇒ $^4C_2 = 6$ Parameters $[Z, Y, g, h, T, T^{-1}]$

(i) Z-Parameter [O.C. parameter]

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$

$Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0}$ $\quad Z_{12} = \frac{V_1}{I_2}\Big|_{I_1=0}$

and so on.

Z_{11}/Z_{22} : Driving pint i/p or o/p impedance when o/p or i/p is o.c.

Z_{12} or Z_{21} : Transfer i/p or o/p impedance when i/p or o/p is o.c.

(ii) Y-Parameter [S.C. para]

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$
$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

(iii) h-Parameter [hybrid para]

$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2$$

$$[h] = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = \begin{bmatrix} h_i\ (\Omega) & h_r \\ h_f & h_o\ (\Omega^{-1}) \end{bmatrix}$$

h_i : input impedance $\quad h_r$ = reverse V/g gain = V_1/V_2

h_f : forward current gain = I_2/I_1 $\quad h_o$ = o/p admittance

(iv) g-Parameter

$$I_1 = g_{11} V_1 + g_{12} I_2$$
$$V_2 = g_{21} V_1 + g_{22} I_2$$

Note: $Z_{11} \neq \frac{1}{Y_{11}}$ [$\because$ S.C $\neq$ O.C]

(v) ABCD / X^{mis^n} parameters

$$V_1 = AV_2 - BI_2$$
$$I_1 = CV_2 - DI_2$$

(vi) T^{-1} parameters

$$V_2 = aV_1 - bI_1$$
$$I_2 = cV_1 - dI_1$$

To remember

$$\begin{matrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{matrix}$$

X_{12}, X_{21} → Reciprocity

X_{11}, X_{22} → Symmetricity

Koi bhi parameter ho (z, y, g, h, T, T^{-1})

Agar X_{12} & X_{21} ka unit same h to $X_{21} = X_{12}$ (reciprocity cond^n)

Agar same ni h to $|X| = 1$

Agar X_{11}, X_{22} ka unit same h to $X_{11} = X_{22}$ {Symm cond^n}

Same nih to $|X| = 1$

Conditions for reciprocity & Symmetricity

	Reciprocity	Symmetricity
Z - para	$Z_{12} = Z_{21}$	$Z_{11} = Z_{22}$
Y - para	$Y_{12} = Y_{21}$	$Y_{11} = Y_{22}$
h - para	$h_{12} = -h_{21}$	$\Delta h = 1$
g - para	$g_{12} = -g_{21}$	$\Delta g = 1$
T - para	$\Delta T = 1$	$A = D$
T^{-1} - para	$\Delta T^{-1} = 1$	$a = d$

Interconversion :

(i) $[Z] = [Y]^{-1}$ or $[Z]^{-1} = [Y]$

(ii) $[g] = [h]^{-1}$ or $[g]^{-1} = [h]$

(iii) $[T] = [T^{-1}]^{-1}$ or $[T]^{-1} = [T^{-1}]$

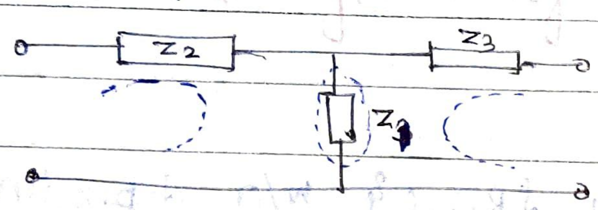
(iv) $h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0} = \frac{1}{y_{11}}$ $\quad$ $h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0} = \frac{y_{21}}{y_{11}}$

$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0} = \frac{Z_{12}}{Z_{22}}$ $\quad$ $h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0} = \frac{1}{Z_{22}}$

$$[h] = \begin{bmatrix} 1/y_{11} & z_{12}/z_{22} \\ y_{21}/y_{11} & 1/z_{22} \end{bmatrix}$$

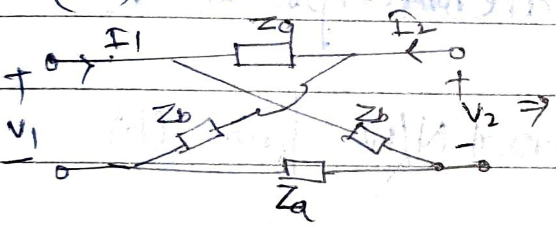
Standard Networks

(i) T N/W

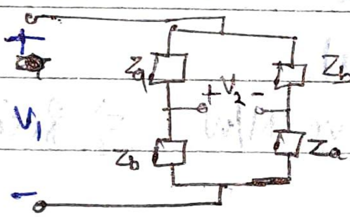


$$[Z] = \begin{bmatrix} Z_1 + Z_2 & Z_1 \\ Z_1 & Z_1 + Z_3 \end{bmatrix}$$

(ii) Lattice N/W

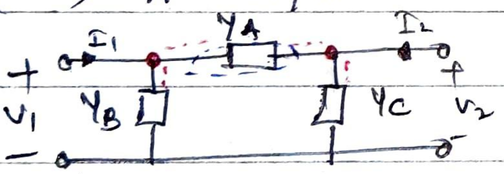


⇒



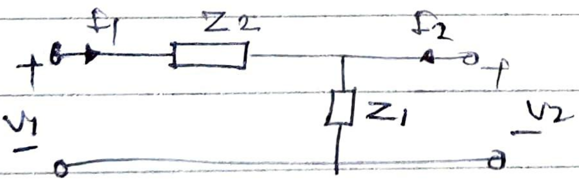
$$[Z] = \begin{bmatrix} \frac{Z_a + Z_b}{2} & \frac{Z_b - Z_a}{2} \\ \frac{Z_b - Z_a}{2} & \frac{Z_a + Z_b}{2} \end{bmatrix}$$

(iii) π − N/W



$$[Y] = \begin{bmatrix} Y_A + Y_B & -Y_A \\ -Y_A & Y_A + Y_C \end{bmatrix}$$

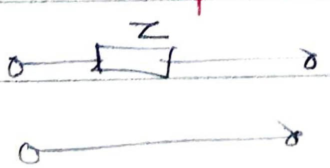
(iv)



$$[T] = \begin{bmatrix} 1 + \frac{Z_2}{Z_1} & Z_2\,(\Omega) \\ \frac{1}{Z_1}\,(\Omega^{-1}) & 1 \end{bmatrix}$$

⇓ Special case

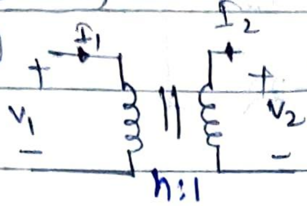
(v)



$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

(vi) Transformer :



$\frac{V_1}{V_2} = n$, $\frac{I_2}{I_1} = -n$

$[h] = \begin{bmatrix} 0 & n \\ -n & 0 \end{bmatrix}$ $[T] = \begin{bmatrix} n & 0 \\ 0 & 1/n \end{bmatrix}$

* (Z-para & Y-para) doesn't exist for Transformer

** Keypoint :

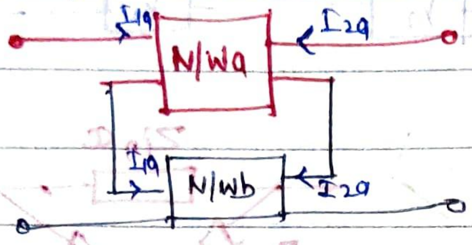
(1.) All complex N/W {R, L, C} w/o dependent source are reciprocal N/W

(2.) Dependent source N/W are non-reciprocal & assymetrical

(3). Passive N/W ⇒ Reciprocal N/W from (1.)

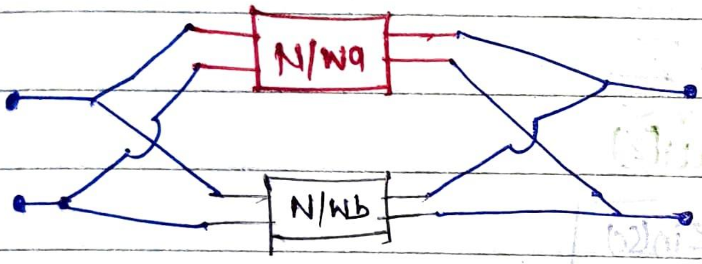
Interconnection of 2-port N/W

(i) Series connection:



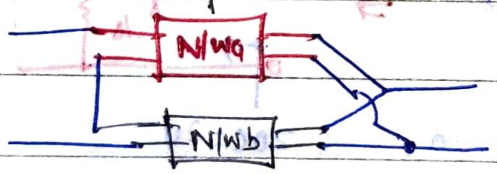
$$[Z]_{total} = [Z]_{N/Wa} + [Z]_{N/Wb}$$

(ii) Parallel connection



$$[Y]_{total} = [Y]_{N/Wa} + [Y]_{N/Wb}$$

(iii) Series-Parallel connection



$$[h]_{total} = [h]_a + [h]_b$$

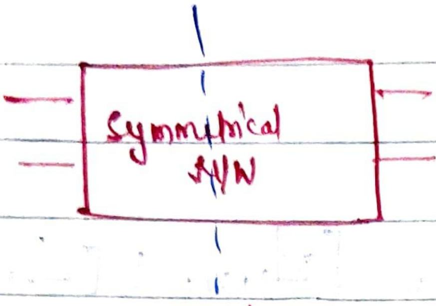
(iv) Parallel-Series connection

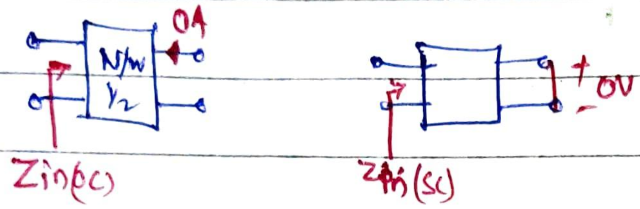
$$[g]_{total} = [g]_a + [g]_b$$

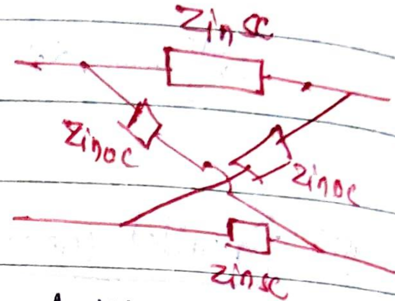
(v) Cascade

$$[T] = [T_a] \times [T_b]$$

⊙ Barlett's Bisection theorem





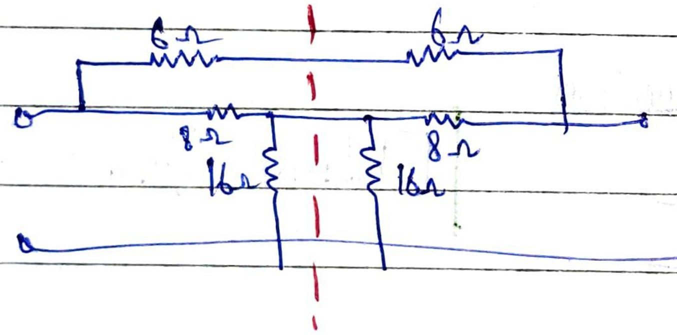


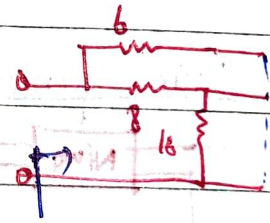
lattice N/W

Characteristic or Image impedance $= \sqrt{\underbrace{\Delta Z}_{\det[Z]}}$

$$\boxed{\Delta Z = Z_{in(oc)} \times Z_{in(sc)}}$$

eg:

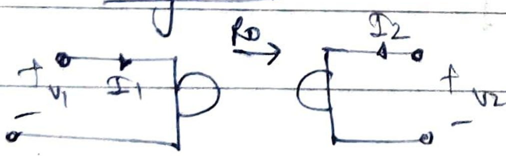




$Z_{oc} = 24$

$Z_{sc} = 6 \| 8 = 24/7\ \Omega$

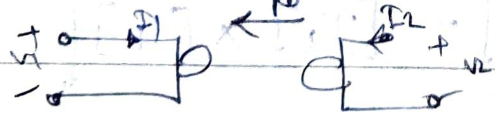
Gyrator



$V_2 = R_0 I_1$

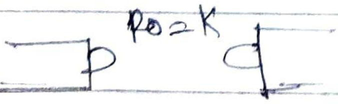
$V_1 = -R_0 I_2$

$$Z = \begin{bmatrix} 0 & -R_0 \\ R_0 & 0 \end{bmatrix}$$



$V_2 = -R_0 I_1$

$V_1 = R_0 I_2$



$V_2 = K I_1$

$V_1 = -K I_2$

* Gyrator is Nonreciprocal device, known as impedance inversion device

Transient & steady state response

[i/p] $x(t) \longrightarrow$ [System] $\longrightarrow y(t)$ [o/p]

- $e = 2.718$; $e^{-1} = 0.368$; $1 - e^{-1} = 0.632$

- $y(t) = y(\infty) + \{y[0] - y[\infty]\} e^{-t/\tau}$
  $y(t)$ can be $I_L(t)$, $V_L(t)$, $I_R(t)$, $V_R(t)$ etc.

  ← Not valid for 2nd order eq^n i.e. more than 1 L or C

- for finite time switching
  $$I_L(t) = I_L(\infty) + [I_L(0^+) - I(\infty)] e^{-\left(\frac{t - t_0}{\tau}\right)}$$
  Same for $V_L(t)$, $I_R(t)$, $V_R(t)$

- $\tau = \dfrac{L_{eq}}{R_{th}}$ $\left[\dfrac{\text{Henry}}{\Omega} = \text{sec}\right]$

- * Laplace Xform is valid everywhere
  * Transient eq^n is valid only for 1st order N/W

- $I_L[0^+] = I_L[0^-]$;
  Calculate $V_L[0^+]$ from ckt by replacing inductor ($I[0^+]$) by current source ($I[0^+]$)

  $$\frac{d\{I_L[0^+]\}}{dt} = \frac{V_L(0^+)}{L}$$

KVL eg: $-V + I_L(t) R + V_L(t)$

diff. $R \dfrac{d I_L(t)}{dt} + \dfrac{d V_L(t)}{dt} = 0$

Put $t = 0$ & solve $\dfrac{d V_L(0^+)}{dt} = -\dfrac{RV}{L}$

$$\frac{d[V_L(t)]}{dt} = L \frac{d^2 I(t)}{dt^2}$$

$$\frac{d^2 I[0^+]}{dt^2} = \frac{1}{L} \frac{d[V_L(0^+)]}{dt}$$

→ $I_L[0^-] = I_L[0^+]$ $\qquad$ $V_L[0^+] = f\,[I_L(0^+)]$

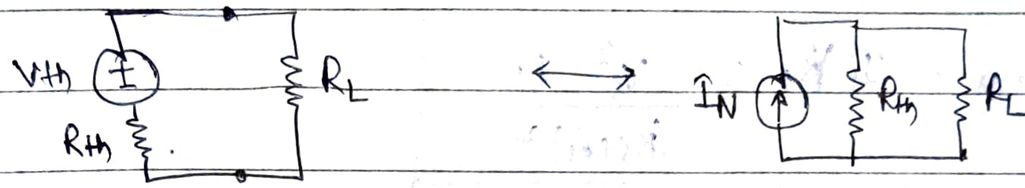
→ $\frac{d}{dt}[I_L(0^+)] = f[V_L(0^+)]$ $\qquad$ $\underbrace{\frac{d}{dt}[V_L(0^+)] = f\,\frac{d}{dt}[I_L(0^+)]}_{\text{from KVL}}$

→ $\underbrace{\frac{d^2}{dt}[I_L(0^+)] = f\,\frac{d(V_L[0^+])}{dt}}_{\text{put } V_L = L\frac{d}{dt} I_L(t)}$

* for impulse and step response go by Laplace.

NETWORK THEOREMS

⊙ $R_{eq} = R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{V_{th}}{I_N}$

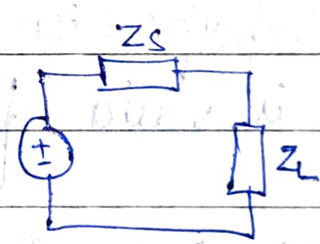


$R_{th} = R_N$, $V_{th} = I_N R_N$

⊙ Maximum Power transfer theorem

*** → In case of fixed load, we choose min. value of R_s for M.P.Xfer.

→ This theorem gives at most 50% η.



Case : 1 $Z_S = R_S$, $Z_L = R_L$

cond^n $\boxed{R_L = R_s}$ $\boxed{P_{Lmax} = \frac{V_s^2}{4R_s}}$

$\boxed{P_{del} = \frac{V_s^2}{2R_s}}$ at M.P.T.

Case : 2 $Z_s = R_s + jX_s$, $Z_L = R_L + jX_L$

cond^n, $\boxed{R_L = \sqrt{R_s^2 + (X_s + X_L)^2}}$

$$\boxed{P_{RL}(max) = I_L^2 R_L = \frac{V_s^2 \, R_L}{(R_s+R_L)^2 + (X_s+X_L)^2}}$$

Case 3: $Z_s = R_s + jX_s$, $Z_L = R_L + j\cancel{X_L}$

condⁿ $\boxed{X_s = -X_L}$

$$\boxed{P_{L\,max} = I_L^2 R_L = \frac{V_s^2 R_L}{(R_s+R_L)^2}}$$

Case 4: $Z_s = R_s + jX_s$, $Z_L = \cancel{R_L} + j\cancel{X_L}$

condn : $\boxed{Z_L = Z_s^*}$

$$\boxed{P_{L\,max} = I_L^2 R_L = \frac{V_s^2}{4R_s}}$$

- Superposition theorem

It is valid for dependent as well as independent N/W

→ $I_0 = I_1 + I_2 + I_3 + \cdots + I_n$

→ $V_0 = V_1 + V_2 + V_3 + \cdots + V_n$

→ $P_0 = (\sqrt{P_1} + \sqrt{P_2} + \sqrt{P_3} + \cdots + \sqrt{P_n})^2$

→ Depending upon direction of both currents

$P_{max} = (\sqrt{P_1} + \sqrt{P_2})^2$ {when I_1, I_2 are in same dirⁿ}

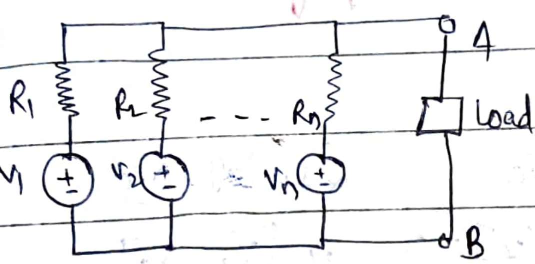
$P_{min} = (\sqrt{P_1} - \sqrt{P_2})^2$

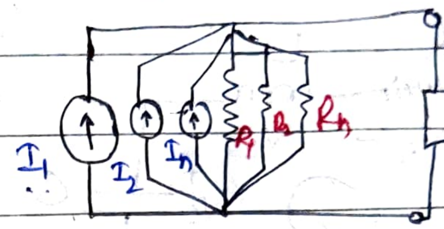
- Reciprocity theorem

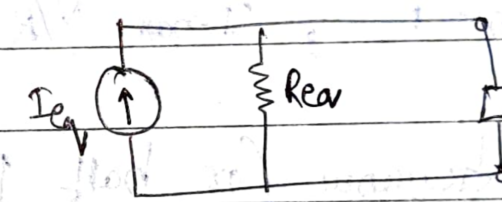
→ Not valid for dependent source N/W

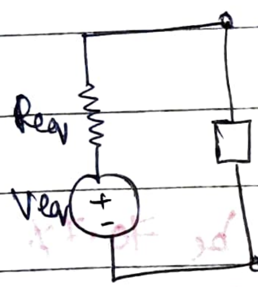
Millman's theorem

(1)







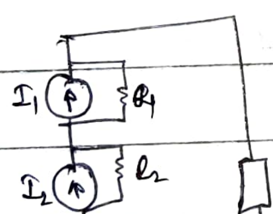


$$I_{eq} = I_1 + I_2 + \dots + I_n = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \dots \frac{V_n}{R_n}$$

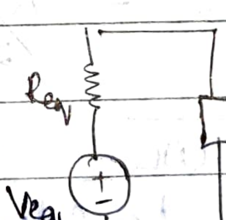
$$R_{eq} = (R_1 \parallel R_2 \parallel R_3 \dots \parallel R_n)$$

$$\boxed{V_{eq} = I_{eq} R_{eq}}$$

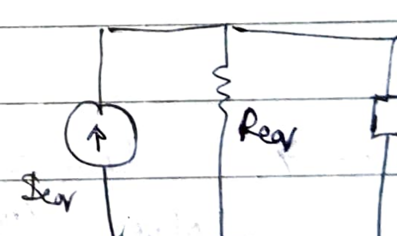
(2)



$\Rightarrow$



$\Rightarrow$



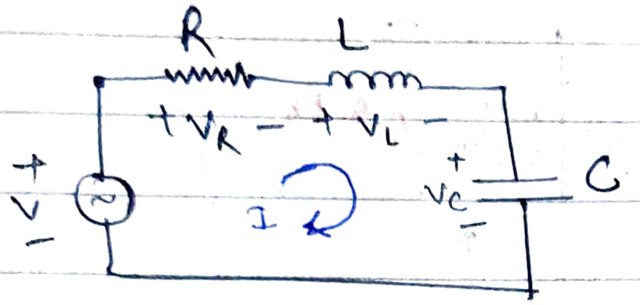
$$V_{eq} = I_1R_1 + I_2R_2 + I_3R_3$$

$$R_{eq} = R_1 + R_2 + R_3$$

$$I_{eq} = \frac{V_{eq}}{R_{eq}}$$

Resonance

(i) Series RLC resonance ckt (V/g Amplifier ckt)



Condⁿ :

- $V_L = V_C$ $\{Im[V]=0\}$
- $Im[Z]=0$ $\Rightarrow \boxed{X_L = X_C}$

$\omega_0 = 1/\sqrt{LC}$ r/s

- $\{Z_{min} = R$, $I_{max} = V/R\}$ → at resonance

- 3dB frequency (or half Power frequency)

frequency at which current response will be 70.7% or $1/\sqrt{2}$ times the maximum value is referred as 3dB frequency.

→ $BW = \omega_H - \omega_L = R/L$ rad/s —(I)

$= f_H - f_L = \dfrac{R}{2\pi L}$ Hz

→ $\omega_0 = \sqrt{\omega_H \omega_L}$ —(II)

Solve (I) & (II) for Calculation of ω_H & ω_L.

→ $Q = 2\pi \dfrac{L_{\text{energy stored}}}{R_{\text{dissipated energy}}} = 2\pi \times \dfrac{C_{\text{energy stored}}}{R_{\text{dissipated energy}}}$

→ $Q = \dfrac{\omega L}{R}$

→ $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$ at resonance

$= \dfrac{\omega_0}{BW}$

{To remember $Z_0 = \sqrt{\dfrac{L}{C}}\ \Omega$

$\dfrac{1}{R} \times \sqrt{\dfrac{L}{C}} = \dfrac{1}{\cancel{\Omega}} \times \cancel{\Omega}$ = unitless} for series RLC

** $V_L = jQV$
$= QV\angle 90^\circ$

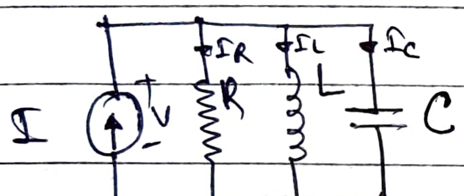
$V_C = -jQV$
$= QV\angle -90^\circ$

for parallel RLC

** $I_L = -jQI$
$= QI\angle -90^\circ$

$I_C = jQI$
$= QI\angle 90^\circ$

(ii) Parallel RLC resonance ckt: (current Amplifier ckt)



$$Y = \frac{I}{V} = \frac{1}{R} + j\underbrace{\left(\frac{1}{X_C} - \frac{1}{X_L}\right)}_{=0 \text{ at resonance}}$$

At resonance:
$V_{max} = IR$
$Y_{min} = 1/R$ $\qquad Z_{max} = R$

→ $BW = \omega_H - \omega_L = \frac{1}{RC}$ r/s
$= f_H - f_L = \frac{1}{2\pi RC}$ Hz

→ $\omega_0 = \sqrt{\omega_H \omega_L}$

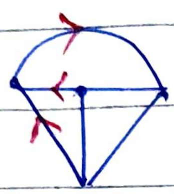
→ $Q_{parallel} = R\sqrt{\frac{C}{L}} = \frac{1}{Q_{series}}$

→ $Q = \frac{\omega_0}{BW}$ for both series & parallel

Graph theory

- Rank of graph, $R = n - 1$ {n = No. of nodes}
- Degree of Node = No. of incoming branches

Σ degree of each node = No. of branches

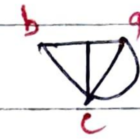


1

D[1] = 2

- If all Node-pair contains single branch b/w them ⇒ complete graph

Complete



Incomplete

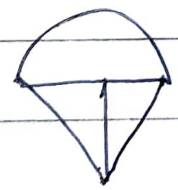
Branch ab = Absent
2 Branches at ac

- Connected graph means it doesn't contains any free node

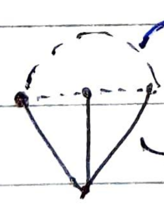
eg:

connected graph
(∵ no free node)

Tree: Subgraph which connects all nodes w/o forming any closed loop.



graph



→ Twigs $= n - 1$

→ Links $= b - n + 1$

* No. of tree of a Completed graph $= n^{(n-2)}$

* Min. no. of edges in a complete graph $= {}^nC_2$

No. of node pair voltages $= {}^nC_2$

Complex Power

Note:→ Avoid Laplace Xform in calculation ~~xxxx~~ in case of sinusoidal input only, as it refers to sinusoidal steady state analysis.

So, if solved by Laplace we will get an exponentially decreasing term say for eg: e^{-5t}

eg: $i(t) = \underbrace{e^{-5t}}_{(=0) \text{ at steadystate}} + \sin 5t$

So, $i(t) = \sin 5t$ is final answer.

$$\frac{dx}{dt} = \sin t$$

$$x = \cos t + c$$